Psychonomic Bulletin & Review
2006, 13 (3), 493-498

Vision-for-action: The effects of object property discrimination and action state on affordance compatibility effects

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When a person views an object, the action the object evokes appears to be activated independently of the person's intention to act. We demonstrate two further properties of this vision-to-action process. First, it is not completely automatic, but is determined by the stimulus properties of the object that are attended. Thus, when a person discriminates the shape of an object, action affordance effects are observed; but when a person discriminates an object's color, no affordance effects are observed. The former, shape property is associated with action, such as how an object might be grasped; the latter, color property is irrelevant to action. Second, we also show that the action state of an object influences evoked action. Thus, active objects, with which current action is implied, produce larger affordance effects than passive objects, with which no action is implied. We suggest that the active object activates action simulation processes similar to those proposed in mirror systems.

A number of authors have emphasized the close link between perception and action. Clearly, perceptual systems evolved primarily to enable organisms to extract information from the visual array to enable actions appropriate to support survival (e.g., finding and pursuing prey, avoiding predators, etc.). Therefore, because of this intimate relationship between vision and action throughout evolution, these systems should not be considered to be completely independent modules (see, e.g., Gibson, 1979; Prinz, 1990).

It is now well established that vision can be converted fluently into action. This seems to be the case even when people have no intention of acting on an object they may be viewing; an action may nevertheless be covertly activated and can influence ongoing behavior (see Prinz & Hommel, 2002). For example, the Simon (1969) effect reveals that although irrelevant to current task goals, the spatial location of a stimulus relative to an effector such as the hand influences processing, whereby, for example, responses are faster when the visual stimulus and the responding hand are on the same side of space. Although there can be somewhat complex relationships between vision and action in Simon-type tasks (see, e.g., Hommel, 1995; Michaels, 1988), the link between vision and action appears to be a ubiquitous finding.

Similarly, in people with lesions to the frontal lobe, the fluent and automatic link between vision and action is revealed. Such individuals, even when told not to respond to an object placed in front of them, nevertheless act on the object in an appropriate manner: They might reach out and grasp a coffee cup, for example, even though verbalizing that they know they should not grasp the object (see, e.g., Lhermitte, 1983). This "utilization behavior" again clearly demonstrates that the actions afforded by an object appear to be automatically encoded, even when no action is required.

The final example is the technique developed by Tucker and Ellis (1998), and this is the focus of the present article. In a range of experiments (e.g., Ellis & Tucker, 2000; Phillips & Ward, 2002; Tucker & Ellis, 2004), it has been demonstrated that even though the grasp response evoked by a visual object is irrelevant to the participant's task, it still appears to be encoded, speeding response when compatible with a current action, and slowing response when incompatible. In one study, participants were required to decide whether an object was upright (press the right key, for example), or inverted (press the left key). If an object was upright and evoked a right-hand grasp, such as a frying pan with its handle oriented toward the right hand, reaction times (RTs) were faster than if the handle was oriented toward the left hand. As this example illustrates, when motor representations such as grasping actions are spontaneously activated by a visual stimulus, responses that are compatible with the evoked action are facilitated, and responses that are incompatible with the evoked action are made more difficult, as indicated by the RT differences.

The present work engages two issues concerned with these automatic vision-to-action processes: The first is the role of attention, and the second concerns the action state of the viewed object. As noted above, Tucker and Ellis (1998) have shown that action affordances appear to be

This research was supported by Economic and Social Research Council Grant RES-000-23-0429, awarded to S.P.T. and A.E.H. Correspondence concerning this article should be addressed to S. P. Tipper, Centre for Clinical and Cognitive Neuroscience, School of Psychology, University of Wales, Bangor, Gwynedd, LL57 2AS, Wales (e-mail: s.tipper@bangor.ac.uk).

evoked automatically. However, there is still the issue of which properties of the visual object are focused on to produce such grasp affordances. To study this, a range of tasks have been employed, for example: deciding whether an object is inverted or upright, deciding whether an object is to be found in a garage or a kitchen, and deciding whether an object is living or man-made. Importantly, in each of these tasks, attention is focused on object properties such as shape and meaning. To know whether an object is inverted, for example, close analysis of its shape is necessary to identify what the object is, and to access memories concerning its normal orientation. Although a reach-and-grasp response is not required, attention is focused on the object's shape information that is necessary to guide such actions. The question we ask here is whether the automatic vision-to-action affordance compatibility effects are observed when attention is directed to a stimulus property that is unrelated to grasp affordances. We contrast the automatic grasp compatibility effects when participants identify the shape of an object (which is a property related to grasping the object) with conditions in which attention is directed to the color of the object (which does not influence grasp).

In both conditions, attend shape and attend color, all of the participants view exactly the same objects (door handles evoking right- or left-hand reach-to-grasp). Consider Figure 1. Panel A shows the square-shaped handle, and Panel B shows the round-shaped handle. Clearly, when participants are required to discriminate these shapes, they are focusing attention on a property of the object that would influence the final stages of grasp as the

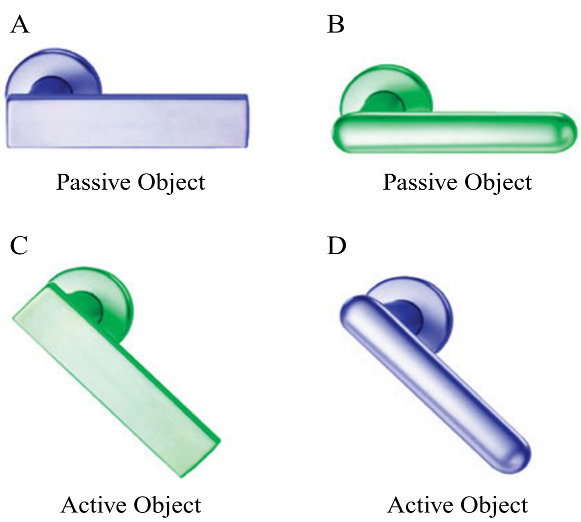

Figure 1. Representation of the stimuli used in Experiment 1. Panels A and B represent the "passive" objects. Panel A shows the square-shaped handle, and Panel B shows the round-shaped handle. These stimuli also varied in color (blue or green) and pointing direction (left or right). Half the participants discriminated shape while ignoring color, and half discriminated color while ignoring shape. Panels C and D show the "active" object state, in which action is implied.

hand comes into contact with the handle. Note, also, that these stimuli vary in color, being tinted blue (Panel A) and green (Panel B). When participants make left and right keypress responses to discriminate color, this property is unrelated to grasp. That is, whether a handle was blue or green would not affect how it was grasped.

We predict that Tucker and Ellis's (1998) grasp affordance effects will be confirmed when participants discriminate door-handle shape (square vs. round). However, it is not known whether similar action affordance compatibility effects will be observed when color is discriminated. It is possible that no such effects will be observed. If this is the case, it would reveal that the grasp evoked by an object can be encoded automatically (i.e., when grasping is not relevant to a person's task), but for this to occur, attention has to be focused on properties of the object, such as shape, that are linked to action.

The second issue these studies engage concerns the nature of the action state of the observed object. We distinguish between "passive" and "active" states of an object. Passive states are the typical form of object representation, in which an object evokes an action, but no action appears to be taking place. This is the situation examined in all studies to date. When a person views a frying pan with the handle oriented toward the right hand, for example, this stimulus clearly evokes an action with the right hand, but there is no sense that the object is actually being acted upon. In other situations, an object state can strongly imply that some force/action is acting on it. Consider panels C and D in Figure 1. These show the door handles depressed. This position of the handle can only be achieved if a force is acting down on the internal spring mechanism. It should be noted that in initial pilot studies, action affordance effects with the door-handle stimuli were very small. Therefore, in an attempt to increase the affordance effects, and also to specifically increase the sense of active object state, we presented short video clips of a hand reaching toward, grasping, and pushing the handle down, prior to starting the experiment (to be described in detail later).

We predict that larger action affordance compatibility effects will be observed in the active object state, because this implies an action evoked by another person. This idea is supported by research from Rizzolatti and colleagues (e.g., di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992), who have shown cells in frontal area F5 of the monkey that respond when the animal makes a particular action, such as a pinch grip to grasp a peanut, but also when the animal observes someone else perform the same action. A substantial range of studies have confirmed the existence of these so-called "mirror" cells in the monkey, and also that similar networks are activated in humans when they observe the actions of other people (e.g., see Rizzolatti & Craighero, 2004, for a review). Of particular pertinence to the present study, Ferrari, Rozzi, and Fogassi (2005) have recently discovered tool-responding mirror cells in the lateral sector of F5. These cells are selectively activated when the monkey observes an experimenter with a tool. Such cells appear to encode the taking possession of an object and modifying its state, as in the act of depressing a door handle in the present study.

It appears, then, that vision–action neural systems simulate observed behavior. It is noteworthy that the mirror system is not necessarily the same as that encoding the action possibilities of viewed objects. This is because, although a subset of cells in F5 respond when a person views an action, these "mirror cells" do not necessarily react when a person views an object that would evoke a particular action. Therefore, when a person is viewing the depressed door handle in the active state, action affordance effects might be more robust because two mechanisms are activated: the previously discussed grasp response, evoked when viewing an object, and a simulation of another person's action that is necessary to account for the active state of the handle.

This idea—that when the depressed handle is viewed, the image strongly implies that action has produced this state of the object—could be questioned, because no action is actually observed. However, although no hand action is visible in the scene, recent work suggests that this is not necessary to activate action simulation or mirror systems. For example, Umiltà et al. (2001) demonstrated that when (1) an object is placed in front of a monkey, (2) the object is occluded by a barrier, and then (3) a hand reaches behind the barrier to grasp the object, the mirror cells of F5 still respond even though the animal cannot directly view the action. Mirror neurons have also been shown to respond to the sound of an action being performed, such as the sound of tearing paper, even though the action cannot be seen (see, e.g., Kohler et al., 2002).

To preview our findings: We do find that the object property participants discriminate is critical for action compatibility effects. When participants analyze shape, action affordance effects are observed; when participants analyze color in the same objects, no effects are observed. Second, when participants analyze the shape of visual objects, the action state appears to influence the action compatibility effects. As predicted, larger effects are observed in the active object state than in the passive object state.

EXPERIMENT 1

Method

Participants. Thirty-two undergraduates from the University of Wales, Bangor, participated for course credit (27 females, 5 males; mean age = 21 years). All of the participants had normal or corrected-to-normal visual acuity, stereopsis, and no color blindness. All except 3 participants reported that they were right-handed. Participants were randomly assigned to one of two experimental groups. All were naive as to the purpose of the study and gave informed consent prior to their participation.

Apparatus and Stimuli. Stimuli were photos of door handles presented in a nonvisible frame measuring 600 × 600 pixels at the center of the screen. All stimuli were displayed on a white background and were viewed on a 19-in. computer monitor (1,280 × 1,024 resolution) from a distance of 57 cm (maintained by use of a chin rest). A gray fixation cross (font: Courier New, size: 18) was visible at the center of the screen before and after the handle appeared.

Handles could appear in 16 different configurations: two colors (green or blue), two shapes (round handle or square handle), two directions (handle pointing to the left or right), and two orientations (one "passive," where the handle was horizontal, and another "active," where the handle was rotated 45º from horizontal). Thus there were $2 \times 2 \times 2 \times 2 = 16$ individual stimuli, examples of which are shown in Figure 1.

Procedure and Design. The participants were seated in front of the display screen in a darkened room and were initially shown a brief video clip consisting of four sequential subclips, each lasting 2 sec: a male/female left/right hand reaching toward and operating a door handle (for an example, see Figure 2).

Each individual trial consisted of a fixation screen presented for 1,000 msec followed by the to-be-responded-to handle presented centrally for 1,000 msec (or until response), which was then replaced by a fixation screen lasting 1,000 msec. A short tone lasting 1,000 msec indicated whether the correct or incorrect response (or lack of response within 1,000 msec) had been made. The participants pressed the space bar to initiate trials.

The participants were instructed to maintain central fixation throughout each trial and to respond to either the shape or color of the door handle that appeared (half of the participants responded to color and half to shape). Emphasis was placed on both speed and accuracy of responses. All responses were made on a computer keyboard presented centrally to the screen and the participant. In the color distinction condition, the participants responded "blue" or "green" by pressing either the A or L key on the keyboard. In the shape distinction condition, the participants responded either "round" or "square" by pressing either the A or L key on the keyboard. Response keys were counterbalanced left and right in each condition.

The participants performed a 16-trial practice block to familiarize themselves with the task, after which the 128 randomized experimental trials began. There was a forced 1-min break halfway through the experimental block. The experiment lasted approximately 20 min total.

Results and Discussion

For each participant, the mean RT for correct responses was calculated for compatible and incompatible conditions for both the passive and active object state conditions. Panels A and B of Figure 3 show the RT effects, and Table 1 shows the error rates. A three-way mixed ANOVA was undertaken on the RTs. There was no significant main effect of the between-participants factor of stimulus discrimination (color vs. shape) [$F(1,30) = .037$, n.s.]. There was a significant effect of object affordance compatibility [$F(1,30) = 12.957, p < .0001$], where RTs were faster for objects compatible with the responding hand. The critical compatibility × stimulus discrimination (color vs. shape) interaction was obtained [$F(1,30) = 15.552, p < .0001$], where compatibility effects were larger when discriminating shape than when discriminating color. There was no main effect of passive or active object state [$F(1,30) = .283$, n.s.]. Neither of the two-way interactions was significant [object state × stimulus discrimination, $F(1,30) = 2.827$, n.s.; compatibility × object state, $F(1,30) = 3.146$, n.s.]. However, the three-way interaction between stimulus discrimination × compatibility × object state was significant [$F(1,30) = 4.776, p < .04$]. Error rates were analyzed analogously to the RT data; the ANOVA revealed no significant main effects or any interactions.

Further ANOVAs analyzed color and shape discrimination RT data separately. In analyzing the RTs in the color

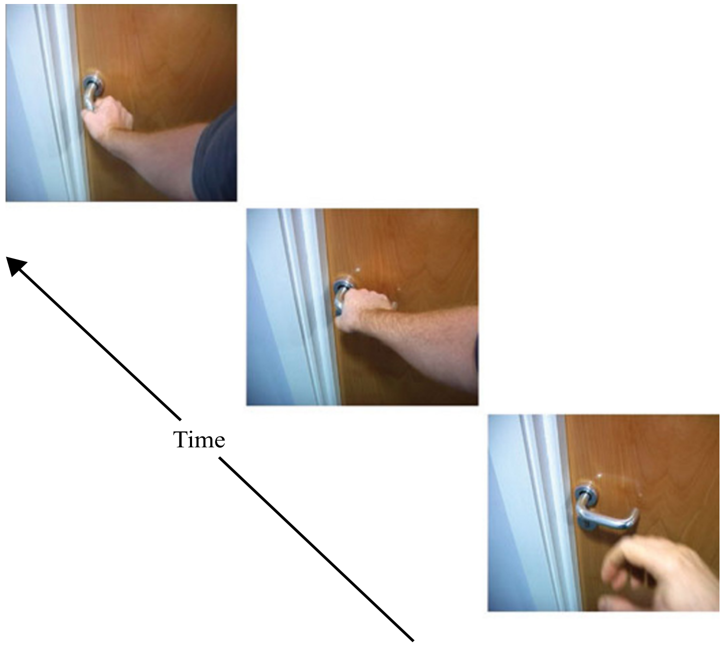

Figure 2. Three frames from the video clip presented to participants prior to testing (male right-hand reach-to-grasp). Four videos were shown to participants. These represented a male and female hand, and reaches with the left and right hands.

discrimination task, we found no main effects for compatibility [$F(1,15) = .077$, n.s.] and object state [$F(1,15) = .664$, n.s.] or interaction [$F(1,15) = .085$, n.s.]. In sharp contrast, shape discrimination showed highly significant action compatibility effects [$F(1,15) = 23.025$, $p < .0001$], but no main effect of action state [$F(1,15) = 2.437$, n.s.]. However, there was a significant interaction between affordance compatibility and object action state [$F(1,15) = 7.823$, $p < .02$]. Planned contrasts of the shape discrimination data were conducted using one-tailed *t* tests, as compatibility effects are predicted a priori from previous studies (e.g., Philips & Ward, 2002; Tucker & Ellis, 1998). Significant action compatibility effects were found for both active and passive action state objects [respectively, $t(15) = 5.494$, $p < .0001$, one-tailed; and $t(15) = 2.009$, $p = .03$, one-tailed].[1]

The results obtained from Experiment 1 appear to provide clear answers to our two research questions. First, the property of an object attended is crucial for observing action affordance effects: They are obtained with shape but not color discrimination. Second, object state does appear to influence affordances: Active objects (handle depressed) produce larger action affordances than passive objects (handle horizontal).

EXPERIMENT 2

This experiment tested whether the action affordance effects observed when participants discriminate object shape are due to the action affordances evoked by the object, rather than simply being due to low-level visual properties such as the orientation of the stimulus (horizontal vs. 45º slope). We reran the shape discrimination task with an additional 16 participants and with two changes: First, the stimuli shown in Figure 4 were used. These were identical to the stimuli in Experiment 1 except that the surround was removed. In pilot studies, no participants reported this object to be a door handle. The second change was that no video clip was shown, to prevent participants from encoding the object as something that could be grasped and depressed like a door handle. All other methods and the procedure were identical to those used in the shape discrimination condition of Experiment 1.

Results and Discussion

The mean RTs for correct responses can be seen in Panel C of Figure 3. The RT effects were analyzed as in Experiment 1. The main effect of action compatibility was nonsignificant [$F(1,15) = 1.58$, n.s.]. The main effect of passive versus active object was also nonsignificant [$F(1,15) = .184$, n.s.], as was the interaction between these factors [$F(1,15) = .009$, n.s.]. Errors in the passive object condition were 3% and 3.6% for compatible and incompatible conditions, respectively, and for the active condition they were 4.1% and 4.1% for the compatible and incompatible conditions. There were no significant main effects or interactions in the analyses of these errors.

Although the stimuli and the shape discrimination task in Experiment 2 were very similar to those of Experiment 1, the subtle differences in the visual stimuli had a dramatic effect. That is, when the objects were no longer perceived as graspable door handles that could be seen in

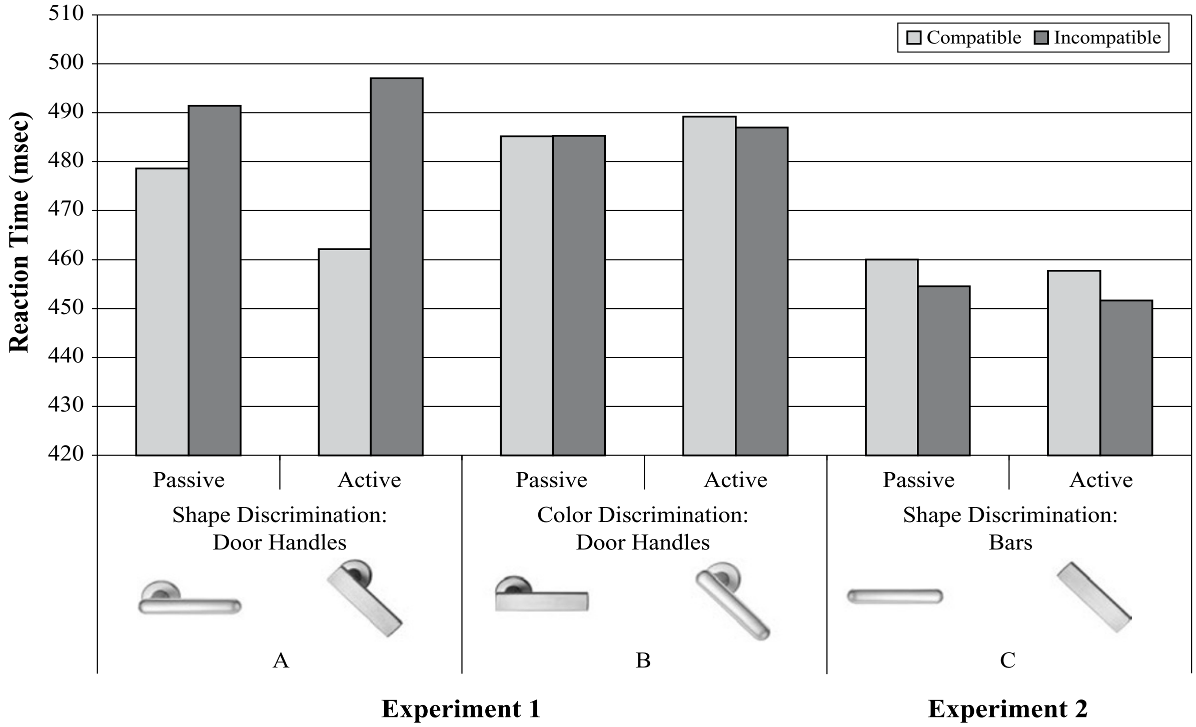

Figure 3. Reaction time data averaged across participants for Experiments 1 and 2. Panel A is shape discrimination of door handles in Experiment 1. Panel B is color discrimination of door handles in Experiment 1. Panel C is shape discrimination of the bar stimuli in Experiment 2.

passive or active states, there were no action affordance effects, and these results did not differ between passive (horizontal) and active (45º slope) stimuli.

GENERAL DISCUSSION

Previous work (e.g., Tucker & Ellis, 1998) has established that when a person views an object, the action evoked by the object appears to be automatically encoded. Thus, even though the grasp response was not relevant to the participant's task, it nevertheless appeared to be encoded, and it facilitated responses that were compatible with it. In the present study, we have confirmed these effects and demonstrated two further properties of these vision-to-action processes.

First, the property of the visual object that is attended is critical for action affordances to be evoked. When participants have to attend to shape (e.g., when discriminating the shape of the door handles), clear action affordance compatibility effects resulted. In sharp contrast, when they attended to the color of the door handles, no action affordance effects were observed. It is important to note two things: First, exactly the same stimuli were observed by all participants; hence, the contrast in affordance effects is based purely on the stimulus property attended. Second, there was no hint of a main effect between color and shape discrimination; hence, both discriminations were resolved at about the same time and were matched for difficulty. Speed of processing has been shown to be important in other vision–action tasks, such as the Simon effect (see, e.g., Hommel, 1994), so this was an important factor to rule out.

R. Ellis (personal communication) notes that action affordance effects can also be produced when object texture is identified. Although texture discrimination might seem similar to color discrimination, we feel there are fundamental differences. For example, as made clear by Gibson (1979), texture gradients, unlike variations in color, are important cues to the 3-D properties of the world (such as shadow). Texture can provide important cues about the

Table 1
Average Error Rates (Percentage Errors) for Compatible and Incompatible Affordance Conditions for Passive and Active Stimulus States in Experiment 1

	Passive		Active	
Discrimination Task	Compatible	Incompatible	Compatible	Incompatible
Shape discrimination	2.8	2.4	3.2	2.8
Color discrimination	2.8	2.8	1.6	3.9

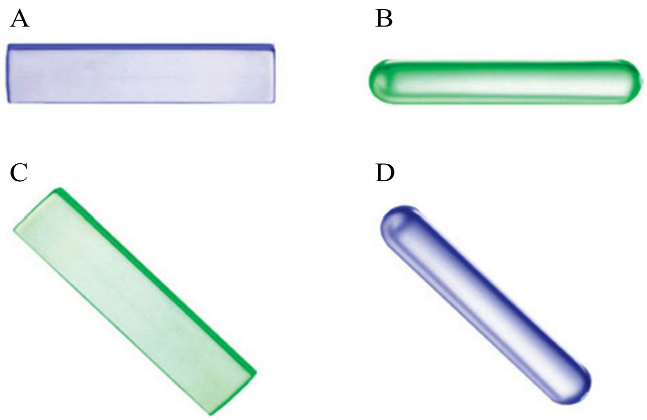

Figure 4. Representation of the bar stimuli used in Experiment 2. They are identical to those shown in Figure 1 (Experiment 1), except for the removal of the hinge/door attachment component.

properties of the 3-D structure of an object that are necessary to guide grasping actions. The existence of affordance effects when encoding object texture also supports the notion that attention must be directed to object properties associated with shape.

The second property of vision-to-action processes revealed by this study concerned the role of the action state of the viewed object. All previous studies have presented what we have termed *passive* objects. Although they evoke specific actions, there is no evidence that action is actually under way when a person views the object. In contrast to this, we presented an *active* action state object: The door handles were depressed by 45º. Our idea was that this implied action state would activate visual–motor systems similar to the mirror systems discussed by Rizzolatti and colleagues. Recent work has shown that even when an action cannot be directly observed, but can be inferred from other visual or auditory cues, the observer simulates the action. In our task, the depressed door handle, combined with the prior priming of this event via exposure to video clips showing such action, strongly implies force acting on the object.

The results obtained clearly support the notion that in the active object condition, there may be both activation of affordance directly from perception of the object (see, e.g., Tucker & Ellis, 1998) and simulation of the inferred grasp and depression action. This combined effect produced more robust effects than when only passive objects were viewed. It is striking that in the color discrimination condition and the bar condition of Experiment 2, there was no hint of an action affordance effect in the active condition, which further rules out low-level stimulus properties such as orientation of the handle.

In sum, two further properties of the vision-to-action processes have been identified. First, activation of action, such as grasp, is not completely automatic. Although such effects can be produced when an object's action affordance is irrelevant to a person's task, nevertheless, attention has to be oriented to action-relevant features of the object, such as shape. Second, there may be two effects mediating action affordances—one evoked by viewing an object, and a second evoked by simulation of observed or inferred actions directed to the object.

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NOTE

1. We conducted a pilot study identical to the shape discrimination task, but without showing participants video clips of hands depressing the door handles prior to beginning the task. The pattern of results was similar to the shape discrimination results of Experiment 1, but weaker: There was no main effect of compatibility, but the compatibility × action state interaction was marginally significant ($p = .08$). Planned contrasts revealed a significant compatibility effect for the active action state but not for the passive action state.

(Manuscript received May 5, 2005;
revision accepted for publication August 28, 2005.)